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# (54) Electron multiplier

(57) An electron multiplier having a housing containing a chain of dynodes 11–22 is structurally combined with a high voltage generation circuit 41, which has a plurality of outputs which provide voltages in monotonically increasing progression and which are connected to the respective dynodes 11–22. The circuit is preferably sandwiched between parts 1, 2 of the housing. By generating the high voltage within the multiplied housing itself the device has no high voltage terminals, the circuit, as shown in Fig. 3, being driven by a square wave A.C. generator 42.

Alternatively the individual multiplication stages may not be connected to the dynodes, but the final high voltage is connected to a resistor chain also sandwiched between the housing parts 1, 2.

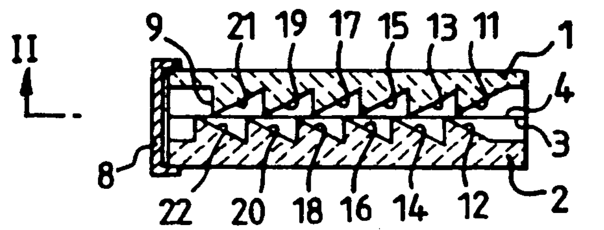


FIG.1.

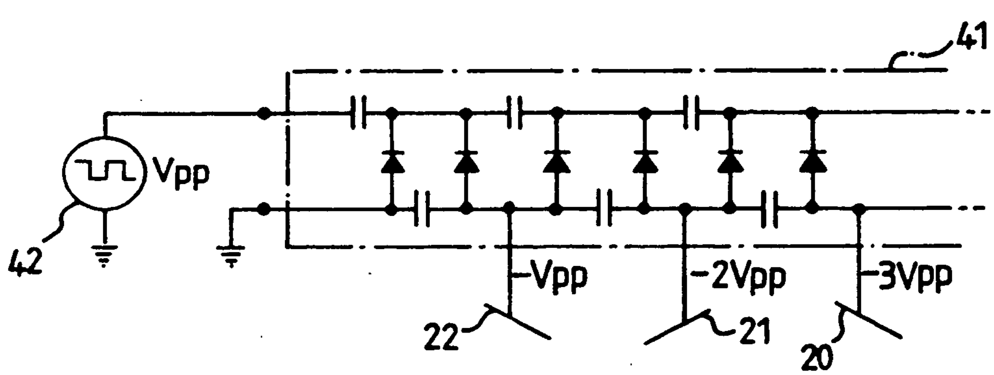


FIG.3.

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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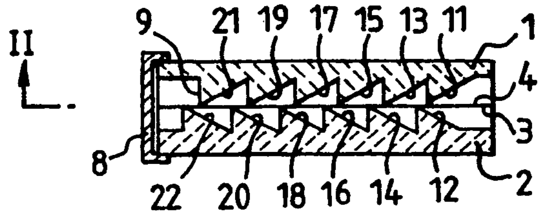


FIG.1.

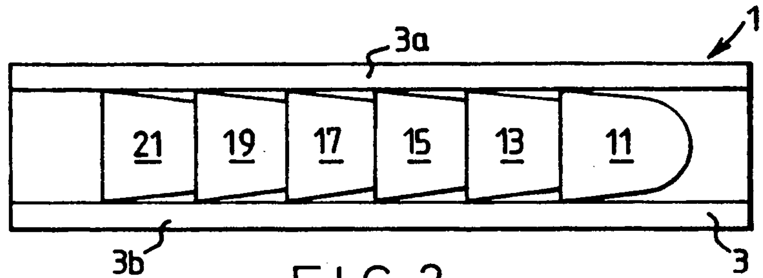


FIG.2.

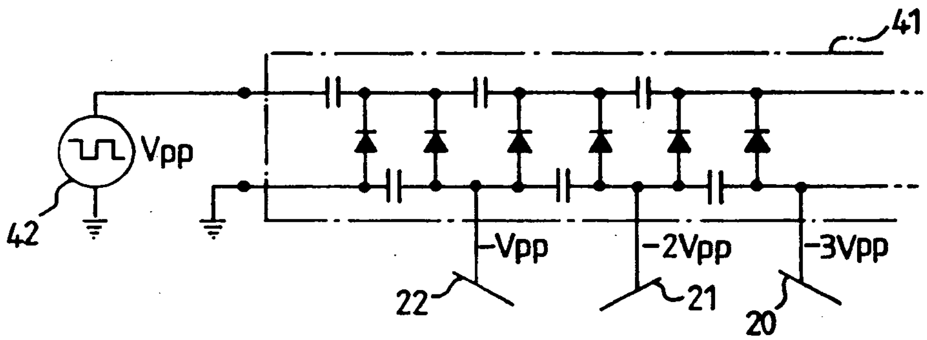


FIG.3.

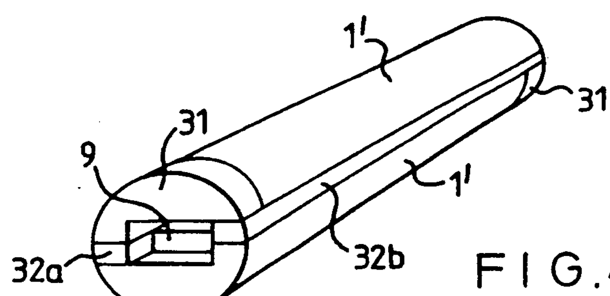


FIG.4.

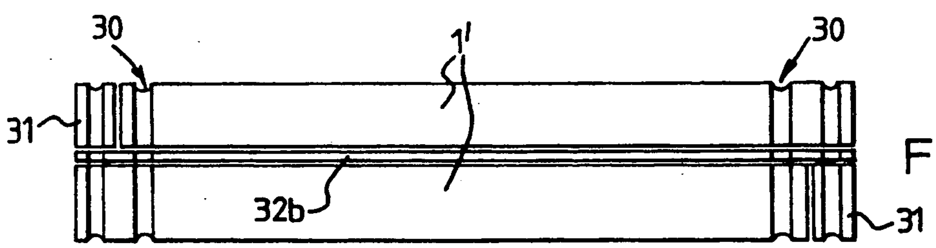


FIG.5.

SPECIFICATION

## Electron multiplier

This invention relates to electron multipliers, which are used to greatly multiply a primary electron flow.

An electron multiplier may, for example, be constructed as an ion multiplier, in which the primary electrons are released from a target impinged upon by a stream of ions. An ion multiplier is, for example, normally incorporated in a mass spectrometer. An electron multiplier may also be constructed as a photomultiplier, in which the primary electrons are emitted from a photocathode.

An electron multiplier comprises a number of dynodes, i.e. electrodes exhibiting the phenomenon of secondary emission. The primary electrons are attracted to and strike the first dynode of the chain. Secondary electrons emitted by the first dynode are attracted to the second dynode, and this sequence continues until the final dynode, which emits electrons which are collected by a collector. The first dynode is at a negative potential with respect to the second dynode, which is in turn at a negative potential with respect to the third dynode, etc.

An electron multiplier with n stages requires a high voltage supply with n outputs having voltages in monotonically increasing progression, usually in arithmetic progression according to iV, where i refers to the $i^{th}$ stage and V is the required potential difference between successive dynodes (e.g. V = 150 volts). The total voltage is nV (e.g. 2 to 4 kV) and is usually applied between a negative potential and earth potential. Conventionally these outputs are supplied from a single high voltage supply together with a resistor chain acting as a voltage divider.

Various designs of electron multipliers are available. In the so-called "Venetian Blind" type, oblique dynodes are stamped out of sheets which are stacked with spacers and interconnected by separate resistors. In the so-called "box and grid" type, bucket-shaped dynodes are mounted on plates which are again stacked with spacers. In the so-called "side cheek" or "fast tube" type, arcuate dynodes are individually mounted on rods extending between parallel side-walls. In each of these designs the dynodes are typically of beryllium copper alloy (BeCu) or silver magnesium (AgMg). They all have the disadvantage of complexity of construction. A simpler type of electron multiplier is known, comprising a tube of glass having a secondary emitting surface which functions both as the dynode chain and as the resistor chain, a large potential difference being applied along the tube, this type is inaccurate and its output is only proportional to its input within a limited range. It is also difficult to manufacture.

The present invention provides an electron multiplier having a housing containing a chain of dynodes, in which the housing is provided with a high voltage generation circuit having a plurality of outputs providing voltages in monotonically increasing progression, the outputs being connected to the respective dynodes.

Such an electron multiplier has the advantage that, in use, when the housing is within a vacuum enclosure, high voltages only appear within the enclosure. This increases safety when operating in hazardous environments. It obviates the need for expensive high voltage cables and connectors.

The preferred high voltage generation circuit comprises a voltage-multiplier rectifier, also known as a Cockcroft-Walton circuit. Such a circuit generates a linearly increasing set of voltages, which can be applied directly to the dynodes. One advantage of such a circuit is that no component of the circuit is exposed to a voltage greater than $V_{pp}$, the peak-to-peak voltage from the A.C. source driving the multiplier. Thus there is no need for high voltage capacitors and diodes.

If the voltages of the successive stages of the multiplier are applied to the successive dynodes, this eliminates the conventional resistor chain, thereby greatly reducing power dissipation. For a 19 $\times$ 1 M$\Omega$ resistor chain at 3 kV the power loss would be about 0.5W. In contrast, assuming a signal current of 1 $\mu$A, the power loss of a 19-stage multiplier would be about 3 mW. This would be of particular advantage in battery-driven devices. Furthermore, power dissipation only occurs when signal current flows. Finally, the accuracy of the voltage series generated is independent of the magnitude of the capacitance values in the multiplier chain, unlike resistor chains, where close tolerance is required.

However, there may be circumstances where it may be convenient or advantageous for the high voltage generation circuit to include a resistor chain acting as a voltage divider. For instance, it may be easier to provide connections between such a resistor chain and the dynodes, thereby reducing manufacturing tolerances.

The electron multiplier preferably comprises a hollow elongate insulating body divided longitudinally into separate parts defining discrete dynode-bearing surfaces spaced along them within the hollow of the body. Such an electron multiplier is simple in construction but without any need to sacrifice accuracy in operation.

The dynode-bearing surfaces may be flat or concave. The dynodes are preferably provided as a coating on the said surfaces of the body, the preferred coating technique being vacuum deposition; vapour deposition could also be used. The dynodes may be of any suitable material which can be surface-treated to provide secondary emission, one such material

being BeCu. preferably the dynodes are intercalated so that there is no free path for stray electrons along the axis of the body. On each longitudinal part of the body, the dynode-bearing surfaces may be alternate, oblique surfaces of a sawtooth configuration.

In a preferred embodiment the high voltage generation circuit is sandwiched between the longitudinal parts of the body, where it cannot produce spurious secondary emission, since it is not exposed to the electron flux in the hollow of the body. A resistor chain may comprise a single elongate coating of resistive material or discrete coatings of resistive material connected by coatings of conductive material (e.g. silver or gold). The resistor chain may be in direct contact with the dynodes or connected to them by branch conductors.

Preferably, the components of the high voltage generation circuit are carried by one or more longitudinal circuit-carrying parts of the body separate from and sandwiched between longitudinal dynode-carrying parts. This simplifies manufacture of the circuit.

Using circuit-carrying parts of identical cross-section and dynode-carrying parts of identical cross-section also simplifies manufacture of the electron multiplier. One circuit-carrying part may carry a voltage multiplier and another a resistor chain.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an axial section through an electron multiplier;

Figure 2 is an enlarged view on line II-II in Figure 1 of part of the electron multiplier;

Figure 3 is a partial circuit diagram of the electron multiplier;

Figure 4 is a schematic perspective view of another embodiment of the body of the electron multiplier; and

Figure 5 is a side view of the body shown in Figure 4.

The electron multiplier illustrated in Figures 1 and 2 has an elongate hollow body which is longitudinally subdivided (substantially along an axial plane) into two separate parts 1,2. Each part is separately moulded in a ceramic material or glass which produces substantially no secondary emission. The parts 1,2 abut along joint faces 3,4 and can be held together by surrounding bands (not shown) or end caps; Figure 1 shows a conductive end cap 8 which serves as the collector.

Each part 1 (or 2) has a sawtooth formation providing transverse surfaces 9 substantially normal to the axis and oblique surfaces facing the opposite part 2 (or 1).

Each oblique surface bears one of a chain of dynodes 11 to 22.

The dynodes may be formed on the parts in the following manner. A number of the parts are placed in a chamber and the surfaces other than the oblique surfaces which are to bear dynodes are masked by suitable screens. The chamber is evacuated and then BeCu is applied to the said oblique surfaces by vacuum deposition. Subsequently, in the same chamber, the BeCu deposit is treated to produce a surface which exhibits secondary emission.

One of the longitudinal sections 3a,3b of the joint face 3, for example, e.g. the section 3a is provided with a voltage-multiplier rectifier circuit 41, shown diagrammatically in Figure 3. Following each multiplication stage the circuit 41 is connected to the respective dynodes 22, 21, 20 etc., as shown. The circuit 41 is driven by a square wave A.C. generator 42.

The capacitors of the circuit 41 may be produced by thin film evaporation onto the ceramic or glass substrate or by wire bonding commercially available "chip" capacitors (glass encapsulated or not) onto a thin film substrate for interconnection to the diodes of the circuit 41 and the dynodes 11 to 22. The diodes may be eutectic die-bonded or wire-bonded chips.

Electrons or ions entering the right-hand end of the hollow body (or electrons emitted from a photocathode) strike the first dynode 11, which emits secondary electrons which in turn strike the second dynode 12, and so on to the (earthed) collector 8.

An alternative embodiment is possible in which the individual voltage multiplication stages are not connected to the dynodes but the final high voltage output of the circuit 41 is connected to a resistor chain sandwiched between the section 3b of the joint face 3 and the opposing section of the joint face 4, each dynode being connected to the resistor chain at an appropriate point. The resistor chain may be constituted by a layer of resistive material deposited on one or preferably both of the joint faces 3,4.

In Figures 1 and 2 the two parts 1,2 are not identical. Figures 4 and 5 shows an embodiment in which both dynode-carrying parts 1′ are identical and can therefore be produced by a single mould. The staggering of the dynodes is achieved by offsetting the two parts 1′ longitudinally, the correct axial spacing being fixed by grooves 30 which are brought into register, as shown, to form circumferential grooves for receiving surrounding bands. The stepped ends of the body can be levelled off by grooved inserts 31, which can be used to carry electrodes, if desired.

Between the dynode-carrying parts 1′ there are two thin, identical, ceramic or glass longitudinal parts 32a, 32b. One part 32a (for example) carries the voltage-multiplier rectifier circuit 41. If a resistor chain is required, this can be provided on the other part 32b.

Various modifications may be made within the scope of the invention. For example: the dynode-bearing surfaces can be concave; the

collector may be provided as a coating within the body; the body need not be straight (e.g. it can be of arcuate or serpentine shape); the voltage-multiplier rectifier circuit may be mounted on the outside of the body, which may be surrounded by a sheathing.

CLAIMS

1. An electron multiplier having a housing containing a chain of dynodes, in which the housing is provided with a high voltage generation circuit having a plurality of outputs providing voltages in monotonically increasing progression, the outputs being connected to the respective dynodes.

2. An electron multiplier as claimed in claim 1, in which the housing comprises a hollow elongate insulating body divided longitudinally into separate parts defining discrete dynode-bearing surfaces spaced along them within the hollow of the body.

3. An electron multiplier as claimed in claim 2, in which the high voltage generation circuit is sandwiched between the longitudinal parts of the body.

4. An electron multiplier as claimed in claim 2, in which components of the high voltage generation circuit are carried by one or more longitudinal circuit-carrying parts of the body separate from and sandwiched between longitudinal dynode-carrying parts.

5. An electron multiplier as claimed in claim 4, hving two circuit-carrying parts of identical cross-section and two dynode-carrying parts of identical cross-section.

6. An electron multiplier as claimed in claim 5, in which one circuit-carrying part carries a voltage multiplier and the other carries a resistor chain.

7. An electron multiplier as claimed in any of claims 1 to 6, in which the high voltage generation circuit comprises a voltage-multiplier rectifier.

8. An electron multiplier as claimed in claim 7, in which the voltages of the successive stages of the voltage-multiplier rectifier are applied to the successive dynodes.

9. An electron multiplier as claimed in any of claims 1 to 7, in which the high voltage generation circuit includes a resistor chain acting as a voltage divider.

10. An electron multiplier substantially as described with reference to, and as shown in, Figures 1 to 3 or Figures 4 and 5 of the accompanying drawings.

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